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MANUFACTURING METHODS AND TECHNOLOGY (MM AND T) PROJECT TO ESTA--ETC(U)
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COMBINED FOURTH AND FIFTH QUARTERLY REPORT

MANUFACTURING METHODS AND TECHNOLOGY PROJECT TO ESTABLISH PRODUCTION TECHNIQUES TO MANUFACTURE RIGID ARMOR FOR RADAR ANTENNA HARDENING

(11)

LEVEL III

REPORT PERIOD

1 March 1978 TO 31 AUGUST 1978

TECHNICAL SUPPORT DIRECTORATE
UNITED STATES ARMY ELECTRONICS
RESEARCH AND DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY

PREPARED UNDER CONTRACT NO. DAAB07-77-C-0476

Approved for public release; distribution unlimited.

PREPARED BY

SWEDLOW, INC.

12122 Western Avenue, Garden Grove, California 92645

NOTICES

This project has been accomplished as part of the US Army Manufacturing Methods and Technology Program which has as its objective the timely establishment of manufacturing processes, techniques or equipment to insure the efficient production of current or future defense programs.

A057 983

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

~~4. TITLE (and Subtitle)~~
6 MANUFACTURING METHODS AND TECHNOLOGY (MM and T) PROJECT TO ESTABLISH PRODUCTION TECHNIQUES TO MANUFACTURE RIGID ARMOR FOR RADAR ANTENNA HARDENING.
AD-A057983 / AD-A067888

5. TYPE OF REPORT & PERIOD COVERED
Combined Fourth & Fifth Quarterly Report 1 Mar 1978 to 31 Aug 1978

~~6. PERFORMING ORG. REPORT NUMBER~~
14 SI-ER-915-4-5

~~7. AUTHOR(s)~~
10 R. Doerr

~~8. CONTRACT OR GRANT NUMBER(s)~~
Contract No.
15 DAAB07-77-C-0476

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Swedlow, Inc.
12122 Western Avenue
Garden Grove, CA 92645

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
TECHNICAL SUPPORT DIRECTORATE
U.S. ARMY ELECTRONICS RESEARCH & DEVELOPMENT CMD
FORT MONMOUTH, NEW JERSEY

12. REPORT DATE
11 Octo[redacted]1978

13. NUMBER OF PAGES
22

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
12 30p.

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

9 Quarterly rept. no. 4 and 5,
1 Mar-31 Aug 78,

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Armor
Panel
Polymeric
Radar Antenna Hardening

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

(See reverse side.)

402 550 Gu

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

79 04 25 051

Block No. 20

ABSTRACT

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Test specimen fabrication was begun using this material. Both full scale and subscale specimens were fabricated.

Thirty-two subscale and twelve full scale test panels were fabricated under a variety of preconditioning steps and molding conditions.

The specimen fabrication results were evaluated and a molding procedure developed for the initial engineering sample molding trial.

A technique for creating a vacuum chamber between caul plates was developed. This procedure which utilizes a silicone rubber seal on an aluminum frame was tested on both subscale and full scale specimen fabrication.

Surplus orientation equipment was purchased, inspected, and stored at Swedlow.

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1.0 PURPOSE

The purpose of this program is to establish production techniques and production capabilities for the manufacture of armor panels. The armor panels are intended for use with flat radar antenna to provide protection from munitions fragments.

The armor panels will be flat molded sheets of various sizes and edge finishes. The sheets will be molded from cross-plied assemblies of unidirectionally oriented, blown film made from a dielectric grade polypropylene. A protective over lay will be molded into the panel surfaces and camouflage will be incorporated in or onto a portion of the panels.

The program is divided into four tasks as described below:

Step 1 Engineering Samples

Two sets of two each panels will be produced in order to demonstrate the ballistic capabilities of the selected materials and processes.

Step 2 Confirmatory Samples

Ten sets of two each panels of various sizes, thicknesses, and camouflaging methods will be produced in order to demonstrate the total capabilities of the panels in regards to environmental stability, electronic transmission, and ballistic characteristics. In addition, camouflaging techniques and panel trim and edge fusing will be demonstrated.

Step 3 Pilot Run

Thirty-two sets of two each panels will be produced in order to demonstrate the capacity of each production step and verify the capability of the line to fabricate at an acceptable rate.

Step 4 Production Capability Demonstration

An in-plant demonstration will be held in order to show the production capabilities of the pilot production line to invited representatives of industry and government.

The first quarterly report described in detail the program objectives, tasks, and schedule.

2.0 INTRODUCTION

The following is a combined report for two quarterly periods covering the time period from March 1, 1978 through August 31, 1978.

During this period the oriented film material supply problem was resolved and sufficient mandrel cross-plied material was received to support the program.

It was also determined that the balance of the oriented film required for the contract would be government supplied.

Additionally, surplus film orientation equipment was purchased that provides the basic components of a film orienting line if such a line is required for future film production.

Testing during this period covered both subscale and full scale process development. The problems and results are discussed in this report.

In addition, special tooling was developed to create a between caul plate vacuum chamber. The design and development of this tooling is also described in this report.

3.0 ORIENTED FILM

3.1 Cross-Plied Oriented Film Pads

During this period ninety cross-plied film pads were received. These pads were mandrel cross-plied by Engineering Technology of Salt Lake City from a film extruded and oriented by Phillips Chemical Corporation.

The cross-plied pads were wound to a nominal areal density of 1.25 lbs/sq ft and cut into 38" x 50" pads.

Material for the balance of the program will be oriented by AMMRC Watertown, Mass., and supplied as government furnished material. The cross-plying task will again be performed by Engineering Technology.

3.2 Film Orienting Equipment

As an extension of the program, surplus film orientation equipment was purchased from Phillips Fiber Corporation. This equipment originally setup as a part of two film orientation lines, includes draw rolls, restraining rolls, and radiant heat ovens.

Required in order to setup this line would be the refurbishment of the surplus equipment, the addition, of off-winding and on-winding stations, and an upgrading or replacement of the control equipment.

Swedlow has completed an inspection of the surplus equipment and has prepared proposals covering equipment setup costs.

The surplus equipment is presently being stored at Swedlow pending a decision on its use.

4.0 TEST SPECIMEN FABRICATION

4.1 General

During this report period thirty-two subscale specimens have been fabricated. The specimens were prepared in order to evaluate various steps in the molding process as well as preconditioning steps.

In addition, twelve full scale specimens were molded so that scale up problems and production tooling and equipment could also be evaluated.

These forty-two specimens were molded under a variety of preconditioning and molding procedures that are described in the next paragraphs.

4.2 Description of Molding Procedures

4.2.1 Materials

The first six specimens were hand cross-plied from a roll of film supplied by AMMRC and received November 30, 1977. The balance of the specimens were molded using material cross-plied by Engineering Technology of Salt Lake City and received March 23, 1978.

4.2.2 Preconditioning

Preconditioning included low vacuum (20-25 inches Hg) application for various time periods, low vacuum in conjunction with an oven heating cycle, and low vacuum followed by a high vacuum (29 inches Hg minimum). A preconditioning at a very high vacuum (4×10^{-4} Torr) in a high vacuum chamber was also used prior to vacuum bagging of one specimen.

4.2.3 Molding Conditions

Specimens were laminated under various evacuation conditions. Included were film stacks molded under the following conditions:

Film stacks uncontained	No vacuum
Film stacks vacuum bagged	1) Low vacuum 20-25 inches Hg
	2) High vacuum 29 inches Hg minimum

Film stacks evacuated in a chamber created by making a seal between the caul plates	High vacuum 29 inches Hg minimum

The molding pressure used to fabricate the forty-two sample panels ranged between 2000 and 3000 psi with 2200 psi being used on the majority of the samples.

In order to evaluate a possible thickness control method, some panels were molded using die stops set to the nominal panel thickness. In this case full molding pressure is maintained until the die reached the stops. At this point and during cool down, the effective pressure rapidly drops.

Figure 1 on the following page shows three different procedures used during the molding of the samples.

4.2.4 Molding Containment

Specimens were molded both between open press platens and in containing matched metal molds. In both cases various edge constraints were employed.

Specimens molded between platens were either unrestrained film stacks between caul plates with no edge pressure or vacuum bagged specimens with a side pressure of less than 15 psi.

Specimens molded in the containing mold also have several varieties of edge constraint and edge pressure. Six of the specimens were cut to fit the cavity with various clearances used. These specimens could have edge pressure up to the panel molding pressure (2000 psi nominal) depending on clearance and film stack hydraulic characteristics.

Other specimens were molded using foamed aluminum spacers around the edge of the film stack. This open cell foam has a compressive strength of approximately 100 psi and this limits the effective edge pressure to this value.

4.2.5 Temperature Monitoring

All specimens were monitored by using .003 - .006 inch diameter thermocouples at the specimen mid-stack. Panel surface temperatures were also monitored by inserting thermocouples into the top and bottom caul plates.

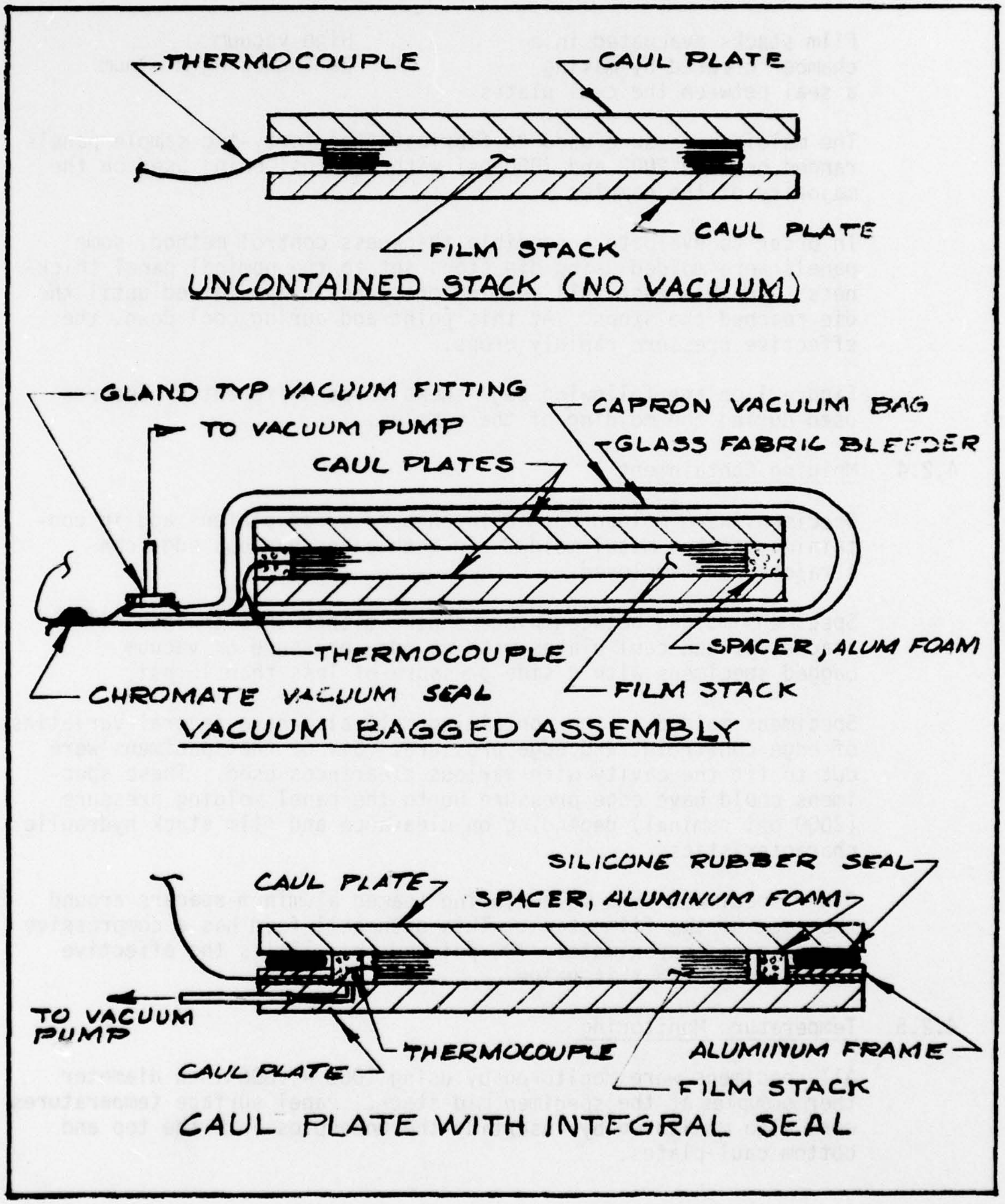

FIGURE 1. EVACUATING PROCEDURES

In the cases where the mid-stack thermocouple was stretched, broken, or otherwise rendered non-functional, the lamination cycle was completed by utilizing a caul plate temperature or time cycle.

4.2.6 Laminating Equipment

Subscale panel moldings were done in a 50-ton hydraulic laboratory press equipped with electrically heated platens and thermostatically controlled.

The full scale samples were molded in a 2000 ton hydraulic press. The match steel mold and platens were steam heated with the temperature controlled by steam pressure regulation.

4.2.7 Molding Results

Table I presents a summary of the specimen molding results. The compilation includes an identification of the materials used, preconditioning steps, a molding cycle description, and comments on final molding results.

TABLE I. SUMMARY, SPECIMEN MOLDING RESULTS

Sample Id. Film Mfgr. Date Rec.	Sample Size Material Cross-Plied by	Prot'v Film	Peel Ply	Precondition	Lamination Cycle: Rise (Min)	Dwell (Min)	Cool Down (Min)	Max Temp (°F)	Molding Vacuum (In Hg)	Molding Press (psi)	On Stop	Comments
021778-1 Phillips 11-30-77	.35 x 8 x 8 Marlex 9317 Hand	No	No	15 Hrs. at 25 in Hg	46	20	36	355	None	2370	Yes	Top side milky, opaque Bottom translucent, partial delamination
022078-1 Phillips 11-30-77	.38 x 8 x 8 Marlex 9317 Hand	No	No	15 Hrs. at 25 in Hg	20	5	69	348½	None	2370	No	Translucent, delaminations both surfaces, internal delaminations, internal wrinkles
030178-1 Phillips 11-30-77	.40 x 8 x 8 Marlex 9317 Hand	No	No	15 Hrs. at 25 in Hg	100	30	75	336	None	2370	No	Delamination or non-lamination throughout. Steam problem could not get desired temperature.
030278-1 Phillips 11-30-77	.33 x 8 x 8 Marlex 9317	No	No	15 Hrs. at 25 in Hg	54	55	50	345	25	2370	No	Delamination top and bottom side. Cloudy appearance at delamination.
031078-1 Phillips 11-30-77	.28 x 8 x 8 Marlex 9317 Hand	No	No	Vacuum bag in oven 25 in Hg 200°F-48 Hrs	42	40	60	348	25	2370	Yes during cool down	Delamination, milky appearance both surfaces (cauls degreased with special care)
031478-1 Phillips 11-30-77	.33 x 3½ x 3½ Marlex 9317 Hand	No	No	15 Hrs. at 25 in Hg	70	15	17	348	None	2000	No	Translucent, slight surface delamination on one corner both top and bottom sides
031478-2 Phillips 11-30-77	.35 x 3½ x 3½ Marlex 9317 Hand	No	No	20 Hrs. at 25 in Hg	45	15	10	348	25	2000	No	Translucent, surface and subsurface delamination
031478-3 Phillips 11-30-77	.39 x 3½ x 3½ Marlex 9317 Hand	No	No	19 Hrs. at 25 in Hg and 200°F	43	15	Not recorded	349	25	2000	No	Translucent, edge delaminations, internal wrinkles

Table I - Continued

Sample Id. Film Mfgr. Date Rec.	Sample Size Material Cross-Plied by	Prot'v Film	Peel Ply	Precondition	Lamination Cycle Rise (Min)	Dwell (Min)	Cool Down (Min)	Max Temp (°F)	Molding Vacuum (In Hg)	Molding Press (psi)	On Stop	Comments
0403-78-1 Phillips 3-23-78	.89 x 12 x 12 Marlex 9317 En-Tech Wound	No	.005 Nylon	None	49	None	Not re-cord-ed	352	29	2950	No	Milky opaque both surfaces, surface delamination bottom side
040578-1 Phillips 3-23-78	.37 x 12 x 12 Marlex 9317 En-Tech Wound	No	No	72 Hrs at 25 in Hg	132 Min Lost T C			?	None	2000 2200	No	Trapped air and surface delamination. (Molded in 12 x 12 chase mold-steam pressure req'd burst plumbing)
					Removed from bag and loaded into 12 x 12 chase mold (net molding)							
040578-2 Phillips 3-23-78	.31 x 12 x 12 Marlex 9317 En-Tech Wound	No	No	6 Days at 25 in Hg	60	10	25	350	None	2360	Yes Dur-ing cool down	Milky and opaque through out. Some edge delami-nation (run with 040578-3)
040578-3 Phillips 3-23-78	.31 x 12 x 12 Marlex 9317 En-Tech Wound	No	.005 Nylon	6 Days at 25 in Hg	60	10	25	350	29	2360	Yes Dur-ing cool down	Milky and opaque. Slight edge delamination (run with 040578-2)
041978-2 Phillips 3-23-78	.34 x 12 x 12 Marlex 9317 En-Tech Wound	No	No	15 Hrs. at 25 in Hg	50	5	55	345	None	2950	Yes Dur-ing cool down	Translucent, good mid-panel both sides, de-lamination around edge
042478-1 Phillips 3-23-78	.38 x 12 x 12 Marlex 9317 En-Tech Wound	No	No	15 Hrs. at 25 in Hg	Lost T.C.			?	None	2950	Yes Dur-ing cool down	Translucent with some cross-ply mark off. Small amount of edge surface delam. Warped 1/8-inch corner to corner

Table I - Continued

Sample Id. Film Mfgr. Date Rec.	Sample Size Material Cross-Plied by	Prot'v Film	Peel Ply	Precondition	Lamination Cycle: Rise (Min)	Dwell (Min)	Cool Down (Min)	Max Temp (°F)	Molding Vacuum (In Hg)	Molding Press (psi)	On Stop	Comments
042478-2 Phillips 3-23-78	.38 x 32 x 42 Marlex 9317 En-Tech Wound	No	No	15 Hrs. at 25 in Hg	70	2	Not Recorded	345	None	2200	Yes	Molded net in 32 x 42 die mold. Gross delaminations top, bottom surfaces and edges. Warpage to ¼-inch.
					Removed from bag and molded in 32 x 42 chase mold (net molding)							
042778-1 Phillips 3-23-78	.38 x 32 x 42 Marlex 9317 En-Tech Wound	No	No	15 Hrs @ 25 in Hg	1) Lost T.C. 2) 40	 3	 80	? 347	None None	2200 2200	Yes No	Cycled panel twice. Some surface and edge delamination, some trapped air. (Best of full scale net molding) Used 3 mil Aluminum Foil as separator Warpage to 3/8-inch.
					Removed from bag and molded in 32 x 42 chase mold (net molding)							
042778-2 Phillips 3-23-78	.39 x 32 x 42 Marlex 9317 En-Tech Wound	B-503	No	15 Hrs. @ 25 in Hg	34	3	58	350	None	2200	No	Gross delamination of both surfaces (B-503 and the next 3 or 4 plies).
					Removed from bag and molded in 32 x 42 chase mold (net molding)							
050378-1 Phillips 3-23-78	.39 x 32 x 42 Marlex 9317 En-Tech Wound	No	No	15 Hrs. at	21	4	Not Recorded	351	None	2200	No	Translucent, surface delamination of top plies only, some trapped air (Second best of full scale net moldings)
					Removed from bag and molded in 32 x 42 chase mold (net molding)							
050378-2 Phillips 3-23-78	.40 x 24 x 35 Marlex 9317 En-Tech Wound	No	No	15 Hrs. at 25 in Hg	60	13	88	353	28	2200	No	Translucent, small amount of trapped air one area only, small amount of surface delam. Best of full scale molded panels (checked ballistically - OK)
					Stack placed in aluminum foil bag within vacuum bag over two ply of boat cloth bleeder							
061278-1 Phillips 3-23-78	.18 x 4 x 4 Marlex 9317 En-Tech Wound	No	.005 Nylon	36 Hrs. @ 24 in Hg ½ Hrs. @ 29 in Hg	52	7	20	354	29.0	2000	No	Translucent, one small surface delam., small amount of trapped air.

Table I - Continued

Sample Id. Film Mfgr. Date Rec.	Sample Size Material Cross-Plied by	Prot'v Film	Peel Ply	Precondition	Lamination Cycle Rise (Min)	Dwell (Min)	Cool Down (Min)	Max Temp (°F)	Molding Vacuum (In Hg)	Molding Press (psi)	On Stop	Comments
062078-1 Phillips 3-23-78	.40 x 4 x 4 Marlex 9317 En-Tech Wound	NB-81-59-99-5	.005 Nylon	15 Hrs. at 21 in Hg, 45 Min @ 29 in Hg	62	7	15	352½	29.0	2200	No	Translucent, 50% delam of barrier ply each face Small amount of trapped air.
060778-2 Phillips 3-23-78	1 x 4 x 4 Marlex 9317 En-Tech Wound	NB-81-59-99-5	.005Nylon	15 Hrs. at 21 in Hg	Stock slipped @ 344°F			344	29.8	2200	No	Specimen stack slipped
072178-1 Phillips 3-23-78	1 x 4 x 4 Marlex 9317 En-Tech Wound	No	.005Nylon	1 Hr. at 30 in Hg	92	8	30	353	29.9	2200	No	Gross delamination both faces. Internal delamination .4 from top face
072578-1 Phillips 3-23-78	.93 x 4 x 4 Marlex 9317 En-Tech Wound	No	No	15 Hrs. at 25 in Hg	175	Not	Recorded	346	30	2200	No	Heat control problems One face milky, opaque, other face translucent, unlaminated
072678-1 Phillips 3-23-78	.37 x 4 x 4 Marlex 9317 En-Tech Wound	B-503	No	1 Hr. at 30 in Hg	67	5	Not Recorded	351½	29.9	2200	No	Delamination first 4 or 5 plies top side and first 2 or 3 plies on bottom
080178-1 Phillips 3-23-78	.35 x 4 x 4 Marlex 9317 En-Tech Wound	B-503	No	1 Hr. at 30 in Hg	90	35	Not Recorded	353	30.0	2200	No	Delamination trapped air first 3 or 4 plies both sides. High edge flow
080178-2 Phillips 3-23-78	.37 x 4 x 4 Marlex 9317 En-Tech Wound	B-503	No	15 Hrs. at 25 in Hg	47	6	Not Recorded	351	None	2300	No	Surface delaminations both sides.

Table I - Continued

Sample Id. Film Mfgr. Date Rec.	Sample Size Material Cross-Plied by	Prot'v Film	Peel Ply	Precondition	Lamination Cycle Rise (Min)	Dwell (Min)	Cool Down (Min)	Max Temp (°F)	Molding Vacuum (In Hg)	Molding Press (psi)	On Stop	Comments
080278-1 Phillips 3-23-78	.35 x 4 x 4 Marlex 9317 En-Tech Wound	B-503	No	15 Hrs. at 25 in Hg		106 Lost T.C.	Not Recorded	?	None	2200	No	Milky, opaque, surface delamination both sides. High flow
080278-2 Phillips 3-23-78	.39 x 4 x 4 Marlex 9317 En-Tech Wound	B-503	No	15 Hrs. at 25 in Hg	40	13	Not Recorded	354	None	2200	No	Milky, opaque, surface delamination both sides. High flow.
080378-2 Phillips 3-23-78	.38 x 4 x 4 Marlex 9317 En-Tech Wound	No	No	15 Hrs. at 25 in Hg	45	5	Not Recorded	352	None	2200	No	Slight milky appearance, surface delaminations on both sides
080378-2 Phillips 3-23-78	1.1 x 4 x 4 Marlex 9317 En-Tech Wound	No	No	High Vacuum 4×10^{-4} mm for $3\frac{1}{2}$ Hrs.	45 Lost T.C.		Not Recorded	?	30.0	2200	No	Slight surface delamination Non lamination at mid-stack
080478-1 Phillips 3-23-78	.38 x 4 x 4 Marlex 9317 En-Tech Wound	No	No	15 Hrs. at 25 in Hg	65	6	19	$350\frac{1}{2}$	None	2200	No	Sub-surface delaminations both sides
080778-1 Phillips 3-23-78	.35 x 4 x 4 Marlex 9317 En-Tech Wound	No	.005 Nylon	15 Hrs. at 25 in Hg	75	35	17	$350\frac{1}{2}$	None	2200	No	Surface delam. both sides One edge only. Balance of specimen no defects.
080878-1 Phillips 3-23-78	.32 x 4 x 4 Marlex 9317 En-Tech Wound	No	.005 Nylon	1 Hr. at 30 in Hg	65	5	20	$350\frac{1}{2}$	30.0	2200	No	Surface delamination on edges only. Balance of specimen no defects

Table I - Continued

Sample Id. Film Mfgr. Date Rec.	Sample Size Material Cross-Plied by	Prot'v Film	Peel Ply	Precondition	Lamination Cycle: Rise (Min)	Dwell (Min)	Cool Down (Min)	Max Temp (°F)	Molding Vacuum (In Hg)	Molding Press (psi)	On Stop	Comments
080978-1 Phillips 3-23-78	.38 x 4 x 4 Marlex 9317 En-Tech Wound	B-500	.005 Nylon	2 3/4 Hrs @ 30 in Hg	64 Lost T.C.		18	?	30.0	2200	No	Delamination, air entrapment around three edges, otherwise no defects. B-500 to cross-ply peel strength very low.
081078-1 Phillips 3-23-78	1 x 4 x 4 Marlex 9317 En-Tech Wound	B-500	.005 Nylon	3 Hrs. at	1) 163	4	Not Recorded	345½	30.0	2200	No	1) Gross delamination of face plies both surfaces
					2) 65	5	Not Recorded	350	None	2900	No	2) Sample rerun. Decreased surface delamination. Mid-stack delamination as a result of removing too hot
081828-1, -2,-3,4 Phillips 3-28-78	.22 x 4 x 4 Marlex 9317 En-Tech Wound	B-500	.005 Nylon	None	58	5	44	351*	None	775	No	B-500 film pretreated as noted: -1 lightly sanded, -2 perforated, -3 solvent wiped, -4 as-received. All specimens show surface delamination with -4 specimen showing the least.
					-1, -2, -3, -4 specimens run concurrently *Platen temperature							
082178-1	3/8 x 4 x 4				Specimen lost due to premature pressure drop							
082178-2 Phillips 3-28-78	.38 x 4 x 4 Marlex 9317 En-Tech Wound	B-500	No	None	50	10	27**	351½*	None	2200	No	Good appearance - no delaminations. Air worked into panel from edges approx 1/2 inch after removal
					*Platen temperature **Time to air cool to 289°F							
082278-1 Phillips 3-28-78	1 x 4 x 4 Marlex 9317 En-Tech Wound	B-500	.005 Nylon	None	65	17	30**	351*	None	2200	No	Delaminations both surfaces and sub-surface
					*Platen temperature **Time to air cool to 291°F							

Table I - Continued

Sample Id. Film Mfgr. Date Rec.	Sample Size Material Cross-Plied by	Prot'v Film	Peel Ply	Precondition	Lamination Cycle Rise (Min)	Dwell (Min)	Cool Down (Min)	Max Temp (°F)	Molding Vacuum (In Hg)	Molding Press (psi)	On Stop	Comments
082278-2 Phillips 3-28-78	.38 x 4 x 4 Marlex 9317 En-Tech Wound	B-500	.005 Nylon	None	72	10	30**	352*	None	2200	No	B-500 and six cross-plies both sides perforated. Slight air entrapment around edges. B-500 to cross-ply film very low peel strength
						*Platen temperature **Time to air cool to 295°F						
083178-1 Phillips 3-28-78	.380 x 29 x 39 Marlex 9317 En-Tech Wound	No	.005 Nylon	15 Hrs. at 25 in Hg, 2 Hrs. @ 29.8 in Hg	43*	20*	53*	354*	29.9	2200	Yes	Warp and twist 3/4" corner to corner. Trapped air top surface approx 1 sq ft area Trapped air bottom surfaces approx 2 sq ft. Delamination surface plies bottom side approx 20 sq in area. Thickness .372 - .383
						*Platen temperature, mid-panel T.C. broken						
090678-1 Phillips 3-28-78	.39 x 29 x 39 Marlex 9317 En-Tech Assy 6 Pads 9, 10	No	.005 Nylon	15 Hrs. @ 25 in Hg, 3 Hrs. at 30 in Hg	25	20	140	353	30.0	2200	No	Warp approx 3/16 corner to corner. Gross surface delamination first 3-6 plies both surfaces Thickness - .375 - .402
090878-1 Phillips 3-28-78	.39 x 29 x 39 Marlex 9317 En-Tech Wound Assy 6 Pads 11, 12	No	.005 Nylon	15 Hrs 25 in Hg 2 Hrs. 200-245°F and 25 in Hg 3 Hrs @ 30 in Hg	40	20	65	351	30.0	2200	No	Warp approx 3/8 corner to corner. Surface delaminations both sides (approx 70 of surfaces) Thickness - .383 - .401
091178-1 Phillips 3-28-78	1.02 x 29 x 39 En-Tech Wound Assy 6 Pads 1, 2, 3, 8	No	.005 Nylon	1½ Hrs @ 30 in Hg		125 Mid panel T. C. erratic	Over night cool down in press	352*	30.0	2200	No	Warp approx 3/16 corner to corner. Surface delamination first 3-6 plies over 80 of panel both sides. Sub-surface lamination good. Thickness: 1.001 to 1.041

*Platen temperature

4.3 Problem Discussion

Defects that were encountered during specimen fabrications included surface and subsurface delamination or non-lamination, air entrapment, warpage, and opacity caused by excess heat and/or contamination.

The major and repeating defect was delamination, especially delamination of the surface plies. This condition occurred to some extent on all panels.

4.3.1 Delamination

As noted above, delamination was a major and common defect. The following general observations are made in connection with the degree of delamination associated with various processing variables.

Process Variable	Degree of Delamination: Increased	Decreased	Not Affected
Increased panel size	X		
Increased time/temperature		X	
Addition of protective plies	X		
Discontinuity at surface	X		
Aluminum foil separator		X	
Oven pre-drying cycle (under vacuum)			X

It can also be noted that the delaminations were generally associated with the edges of the panel and the outer plies and were not associated with apparent high pressure areas.

Possible causes of the delamination problem are:

1) Non-lamination due to variations in effective pressure (caused by variations in stack thickness, caul plate variations, or material edge flow during cure).

2) Non-lamination due to contamination.

3) Non-lamination or delamination due to trapped moisture or other outgasing medium.

Process changes that will be made in order to up-grade processing steps and to minimize delamination causes are noted below:

1) Increased dwell time.

2) Use of aluminum foil separator.

3) Additional film preconditioning steps designed to aid in moisture removal.

4.3.2 Air Entrapment

Trapped air has been an intermittent problem in the smaller samples and has always been present to some extent in the full size panels.

Longer, higher temperature laminating cycles tend to decrease the problem as does additional dwell time at the higher temperature.

In addition, although panel evacuation has not shown a consistent relationship with air entrapment, the elimination of as much air as possible prior to and during the molding cycle appears to be a necessary step.

In order to accomplish this objective on future moldings, in addition to the specification requirement of 29 inches Hg vacuum minimum, the containment will be sufficiently leak free to maintain vacuum with minimal vacuum drop when the vacuum line is closed off. (The target will be a maximum vacuum drop of 5-inches Hg in five minutes.)

4.3.3 Warpage

Warpage is associated with three different laminating conditions, 1) temperature differences across the panel faces during cool down, 2) low laminating pressure, 3) excessive side pressure during molding.

In order to minimize the first warpage cause, a stepwise cool down cycle utilizing steam pressure control will be initiated.

The second cause dictates the discontinuance of molding to stops. This will prevent pressure loss during cool down.

Net contained die molding will also be discontinued in order to eliminate the third warpage cause.

4.3.4 Opacity Caused by Overheat or Contamination

The heat caused molding problems will be controlled by using a slower stepwise heat-up cycle.

Contamination, however, is a more difficult problem to control in that the contamination source or sources are not positively identified.

Possible contamination sources are:

1) Moisture or contamination within the film pads as received.

2) Contamination from the caul plates or peel ply.

In order to decrease the possibility of moisture entrapment problems, future panels will be preconditioned with two long moisture removal steps. First, the loose film stack will be subjected to a very high vacuum (10^{-4} Torr or lower). The stack will then be evacuated and subjected to an oven heating of 225^{o}F while under a moderate vacuum (20-25 inches Hg) prior to final high vacuum conditioning.

Revised, degreasing/cleaning procedures will be used to minimize contamination from the caul plates. In addition, film surfaces will be covered with aluminum foil in order to further minimize caul plate contamination and eliminate any contamination that might originate from the peel ply.

4.4 Molding Procedure - Engineering Samples

The following is an outline of the proposed procedure to be used in the fabrication of the full scale engineering samples. This procedure incorporates the changes discussed in the preceding sections.

Molding Stack Preparation

Shear pads to over size dimension

Combine pads and remove plies to weight (thickness) required

Cover both surfaces with four plies of protective film (Hercules B-500)

Shear stack to final molding dimensions

Cover both surfaces with 1 1/2 mil aluminum foil

Cover foil with .005 nylon fabric

Position on 3/8 inch thick aluminum caul plate

Position frame seal, foamed aluminum spacers and insert thermocouple at mid-stack (Figure 2 shows 3/8-inch panel and 1-inch panel molding assembly)

Molding Assembly Preconditioning

Place assembly in high vacuum chamber and hold for 24 hours minimum at 10^{-4} Torr minimum

Hold assembly at low vacuum 20-25 inches Hg and 225°F minimum for 15 hours minimum

Hold assembly under 29 inches Hg minimum vacuum for one (1) hour minimum. (Evacuated assembly shall not drop more than 5 inches Hg in five minutes).

Molding Procedure

Load assembly into the matched steel chase mold pre-heated to 225°F

Raise the temperature stepwise by increasing the steam pressure in 10 psi increments until mid-stack temperature reaches 350°F

Hold the assembly at 350 to 353°F for 20 minutes minimum

Reduce temperature stepwise by decreasing temperature in 10 psi increments to 300°F

Turn off steam and force cool the assembly (water cool press platen) to room temperature.

Heat Treating Panel

Holding the panel flat between aluminum plates, heat treat at 200°F for four (4) hours minimum. Heat up and cool down time is to be one (1) hour minimum.

5.0 CAUL PLATE SEALING

5.1 General

During this period a method of sealing the assembly between caul plates was developed. The method utilizes a thick walled silicone rubber tube bonded onto an aluminum frame.

Caul plate to caul plate sealing allows the evacuation of an assembly between caul plates without use of a vacuum bag.

As the seal frames are reusable, they are expected to require much less labor and materials than the vacuum bag method. The method is also expected to be more reliable, efficient, and cleaner than loading into an integral matched mold vacuum chamber.

The arrangement although requiring two separate seals, allows the sealing frame to be placed around the film stack after it is positioned on the lower caul plate. This eliminates the difficult task of dropping the film stack into a cavity or removing a molded panel from a cavity.

Several seal configurations were considered and tested. The thick walled tube seal was selected because it was readily available and had a longer reach and was more compressible than the solid rubber configurations.

5.2 Description, Frame Seals

Figure 2 (Frame Seals) shows the frame seal for both the 3/8-inch thick panel film stack and the one-inch thick panel film stack.

The 3/8-inch panel frame has a 1/32-inch flat silicone seal on one side and a 3/8-inch diameter by 0.080-inch wall tube seal on the other side. Using this frame the chamber must be evacuated through a caul plate vacuum passage.

The frame seal for sealing the one-inch film stack employs two 3/8-inch diameter by 0.080-inch wall tube seals bonded onto a 5/8-inch thick aluminum frame. The configuration allows sufficient room the the vacuum tube to be brought out through the frame.

Figure 3 (Frame Seals Assembly) shows a cross-section of the film assembly seal as it would appear during the molding operation.

The above described frame seals were fabricated during this period and are scheduled for trial at the beginning of the next period.

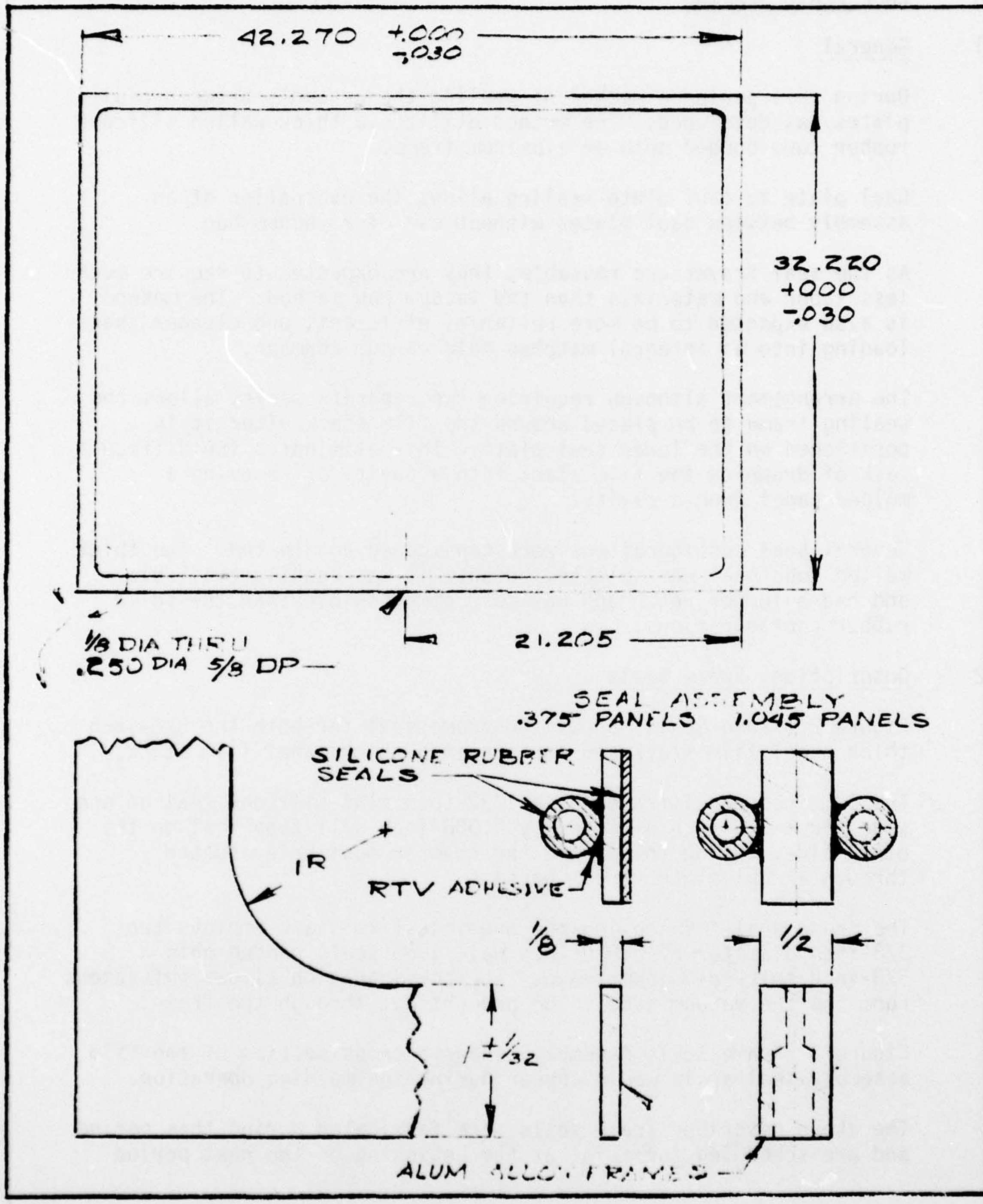

FIGURE 2. FRAME SEALS

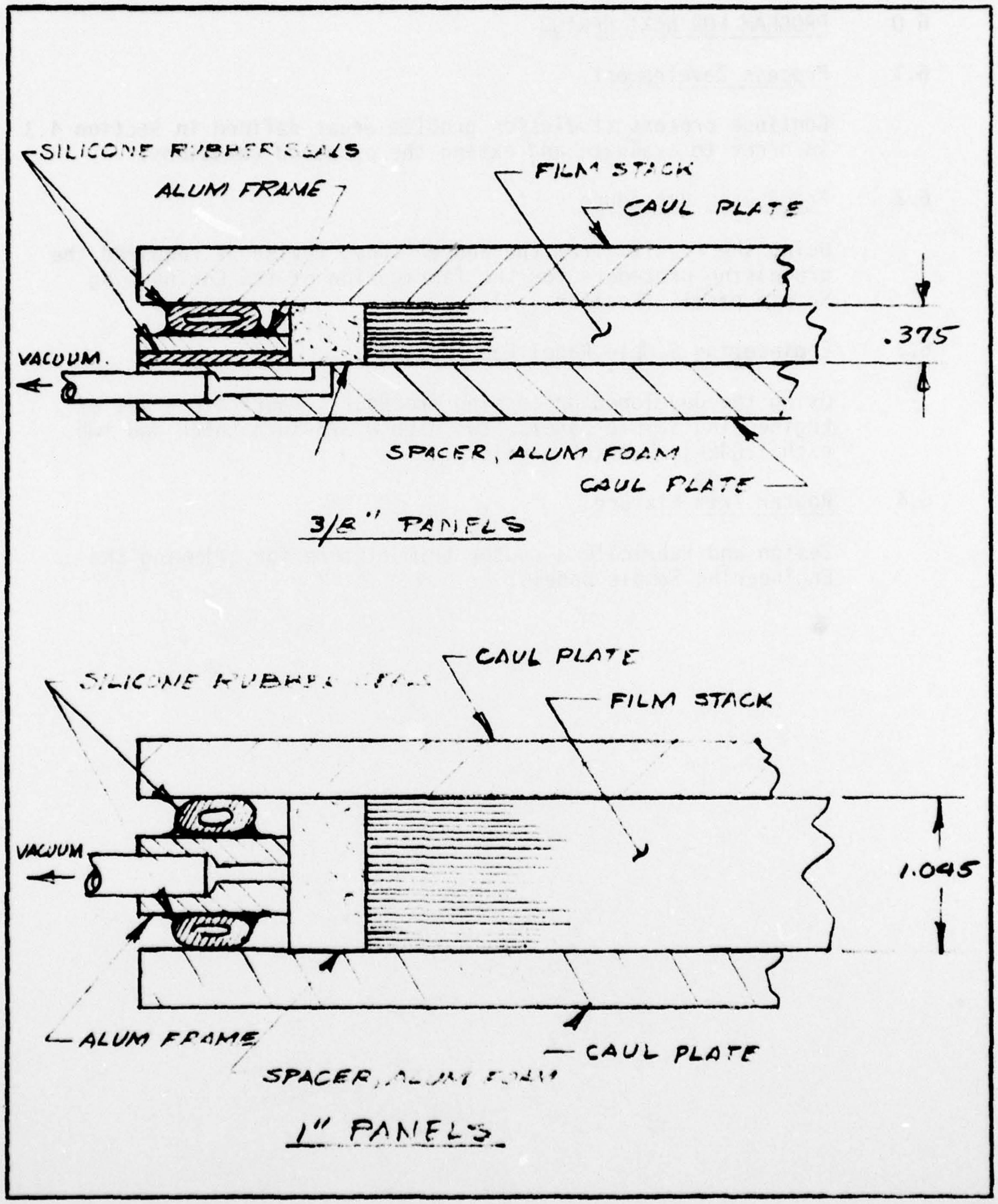

FIGURE 3. FRAME SEAL ASSEMBLY

6.0 PROGRAM FOR NEXT PERIOD

6.1 Process Development

Continue process studies on problem areas defined in Section 4.3 in order to evaluate and extend the proposed solutions.

6.2 Processing Procedure

Using the results from the above study, revise as required the processing procedure for the fabrication of the Engineering Sample panels (Section 3.4).

6.3 Engineering Sample Panel Fabrication

Using the developed processing procedure, fabricate a set of Engineering Sample panels (two each 0.375-inch thick and two each 1.045-inch thick panels).

6.4 Router Trim Fixture

Design and fabricate a router trim fixture for trimming the Engineering Sample panels.